focus error signal and tracking error signal for carrying out focus control and tracking control.

Most of the beam which has entered the beam splitter 30 passes through the reflection plane 30A and introduced via the half wave plate 34 to the polarization beam splitter 38. From this beam, a p-polarized component is introduced via the convex lens 35 and the concave lens 36 to the photo detector 37, whereas an s-polarized component is introduced via the reflection plane 38A, the reflection plane 38B, the convex lens 39, and the concave lens 40 to the photo detector 41. A difference between the p-polarized component from the photo detector 27 and an output signal component from the photo detector 41 is calculated by the differential amplifier 42 and outputted as a magneto-optical signal to the recording/reproduction circuit 4. The recording/reproduction circuit 4 demodulates the magneto-optical signal supplied and outputs the resultant signal from the terminal 5.

On the other hand, in a recording mode, the laser diode 21 is controlled according to a recording signal. Moreover, the magnetic head 29 applies a magnetic field having a predetermined bias to the magneto-optical disc 1. As a result, at a position where the optical spot Sl is formed on the magneto-optical disc 1, a mark (magnetization) corresponding to a recording data is formed, thus recording the data.

FIG. 5 shows a detailed configuration of a movable portion of the optical head unit 3. As shown in FIG. 5, the objective lens 27 and the forward lens 28 are respectively fixed at predetermined positions of a lens holder 71. The objective lens 27 has a numerical aperture of about 0.45. Since this objective lens 27 is used in combination with the forward lens 28, the numerical aperture of the incident is multiplied by about 1.8 and the total numerical aperture of the entire unit consisting of the objective lens 27 and the forward lens 28 is about 0.8.

The mounting positions of the objective lens 27 and the forward lens 28, a distance between these lenses, and a lens assembly error due to a lens inclination angle are determined by the processing accuracy of the lens holder 71. If it is assumed that an optically allowable wave front aberration is $\lambda/4$ (λ is a light wavelength), the allowance of the assembly accuracy is as follows: positioning between the lenses ±80 μm; distance between the lenses ±25 μm; and inclination angle ±0.4 degrees. It is possible to obtain this assembly accuracy by a mechanical processing accuracy.

When a data is recorded or reproduced onto/from the magneto-optical disc 1 by using a lens unit (two-lens unit) having a high numerical aperture, the allowance of frame aberration due to the aforementioned inclination of the magneto-optical disc 1 is remarkably lowered if the disc has a thick substrate. That is, as shown in FIG. 5, in the magneto-optical disc 1, on a substrate 61 is formed a recording layer (MO layer) 62, on which is formed a protection layer 63. The laser beam is applied via the substrate 61 to the recording layer 62. In this embodiment, the substrate 61 has a thickness of 0.1 mm. Thus, the substrate 61 is made thin in comparison to a DVD (0.6 mm), enabling to reduce affects of frame aberration to a disc skew even when using a lens unit having a high numerical aperture.

When θ is assumed to be the lens convergent angle, the numerical aperture NA is defined as sin θ. Consequently, as shown in FIG. 6, if the lens radius is identical, as the numerical aperture NA increases, the working distance D is decreased. That is, as shown in FIG. 6A and FIG. 6B, if the lens radius is identical R1=R2 and the lens numerical aperture NA1 (=sin θ1) of FIG. 6A is smaller than the lens numerical aperture NA2 (=sin θ2) of FIG. 6B, the working distance D1 of the former is greater than the working distance D2 of the latter. In this embodiment, the working distance D is set to 100 μm. This working distance is always maintained by driving the actuator 72 arranged around the lens holder 71 according to a focus error signal.

However, as has been mentioned above, if the substrate 61 has an uneven thickness, spherical aberration is caused in the laser beam. Especially in the present embodiment which employs a two-lens unit having a high numerical aperture, quality of the reproduction signal is significantly deteriorated if the thickness of the substrate changes greatly due to factors caused during a disc production. However, if the thickness allowance of the substrate 61 is assumed to be about ±5 μm, the allowance of the substrate having a thickness of 0.1 mm is ±5%, and it is possible to control the thickness of the substrate 61 within this range. In other words, it the substrate 61 has a thickness having an allowance within ±5%, it is possible to reduce the deterioration of the quality of the reproduction signal caused by generation of spherical aberration within a practical use and to realize a magneto-optical disc capable of recording/reproduction with a high density.

It should be noted that since two-lens configuration is employed, it is possible to obtain a high numerical aperture 0.8 to 1.0 of the lens unit. This enables to realize recording/reproduction with a high density.

Each of the surface 27A and surface 27B of the objective lens 27 and the surface 28A of the forward lens 28 is an aspherical surface. As these surfaces are aspheric, it is possible to increase the allowance for the mounting error.

The thickness of the substrate 61 is preferably 0.1 mm to 0.3 mm because if the thickness is great, the affect from skew is increased.

The working distance D is preferably, for example, 50 μm or above, for if it is too small, dusts on the magneto-optical disc may come into contact with the forward lens 28, damaging the forward lens 28.

Moreover, as shown in FIG. 6C, if a lens having a greater numerical aperture NA2 (NA2>NA1) is used while realizing a working distance D3 (=D1) which is identical to the working distance D1 of the lens having a smaller numerical aperture NA1, the lens radius R3 becomes greater than the radius R1 of the lens having the smaller numerical aperture NA1. As a result, the entire apparatus becomes of a larger size. Consequently, the value of the working distance d is preferably 500 μm or below. In other words, if a lens having a numerical aperture NA of 0.8 is used to obtain a working distance greater than 500 μm, the lens radius becomes very great which cannot be realized in practice.

It should be noted that the explanation has been given above for the magneto-optical disc, but the present invention is also applicable for an optical disc dedicated for reproduction or an optical disc of phase change type requiring no magnetic head.

As has been described above, according to the optical disc recording/reproduction apparatus claimed in claim 1 and the optical disc recording/reproduction method claimed in claim 4, the thickness of the optical disc substrate is 0.3 mm or below and the total numerical aperture of the objective lens and the forward lens is 0.8 or above so that the objective lens and the forward lens are controlled as a unitary block. This simplifies the apparatus configuration and enables to record or reproduce a data with a high density.

What is claimed is:

1. An optical disc recording/reproduction apparatus for recording and/or reproducing data by applying a beam from

an optical head unit through a substrate of an optical disc onto/from a recording layer of the optical disc, wherein said substrate of said optical disc has a thickness of 0.3 mm or below, and said optical head unit comprises:

Sub A2

- an objective lens for converging an incident beam and emitting the beam toward said optical disc;
- a forward lens for converging the beam introduced through said objective lens and applying the beam to said optical disc;
- a lens holder in which said objective lens and said forward lens are fixed; and
- an actuator for driving said objective lens and said forward lens as a unitary block and controlling at least focusing,
- said objective lens and said forward lens having (1) a total numerical aperture of 0.8 or above, (2) a center position shift tolerance of ±80 μm, (3) a distance between the objective lens and the forward lens of 25 μm or less, and (4) inclination angles less than 0.4°.

2. An optical disc recording/reproduction apparatus as claimed in claim 1, wherein said forward lens and said substrate define a working distance of 50 μm to 500 μm.

3. An optical disc recording/reproduction apparatus as claimed in claim 1, wherein said forward lens and said objective lens have aspherical surfaces into/from which said beam is introduced.

4. An optical disc recording/reproduction apparatus as claimed in claim 1, wherein said forward lens and said objective lens are fixed at a predetermined distance in said lens holder.

5. An optical disc recording/reproduction apparatus as claimed in claim 1, wherein said actuator carries out tracking control of said forward lens and said objective lens.

6. An optical disc recording/reproduction apparatus as claimed in claim 1, said apparatus further comprises a magnetic head for applying a magnetic field to said recording layer of said optical disc.

Sub A3

7. An optical disc recording/reproduction method for applying a beam from an optical head having an objective lens for converging and emitting the beam toward an optical disc and a forward lens for converging the beam from said

objective lens and emitting the beam to a recording layer through a substrate of said optical disc so as to record or reproduce data onto/from said recording layer, wherein

- said objective lens and said forward lens are fixed in a holder and are driven as a unitary block for focus control and said substrate of said optical disc a thickness of 0.3 mm or below, and
- said objective lens and said forward lens have (1) a total numerical aperture of 0.8 or above, (2) a center position shift tolerance of ±80 μm, (3) a distance between the objective lens and the forward lens of 25 μm or less, and (4) inclination angles less than 0.4°.

8. An optical head unit for applying a beam through a substrate to a recording layer of an optical disc so as to record and/or reproduce data onto/from said recording layer, said optical head unit comprising:

- a first lens for converging an incoming beam and emitting the beam toward said optical disc;
- a second lens for converging the beam emitted from said first lens and emitting the beam to said optical disc;
- a lens holder in which said first lens and said second lens are fixed at a predetermined distance; and
- an actuator for driving said lens holder so as to carry out at least focus control,
- wherein said first lens and said second lens have (1) a total numerical aperture of 0.8 or above, (2) a center position shift tolerance of ±80 μm, (3) a distance between the first lens and the second lens of 25 μm or less, and (4) inclination angles less than 0.4°.

9. An optical head unit as claimed in claim 8, wherein said second lens and said substrate define a working distance of 50 μm to 500 μm.

10. An optical head unit as claimed in claim 8, wherein said first lens and said second lens have aspherical surfaces from/to which said beam is introduced.

11. An optical head unit as claimed in claim 8, wherein said actuator drives said lens holder for carrying out tracking control.

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